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Haze Removal in Color Images Using Hybrid Dark Channel Prior and Bilateral Filter

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Abstrtract : **-** Haze formation is the combination of airlight and attenuation. Attenuation decreases the contrast and airlight increases the whiteness in the scene. Atmospheric conditions created by floting particles such as fog and haze, severely degrade image quality. Removing haze from a single image of a weather-degraded scene found to be a difficult task because the haze is dependent on the unknown depth information. Haze removal algorithms become more beneficial for many vision applications. It is found that most of the existing researchers have neglected many issues; i.e. no technique is accurate for different kind of circumstances. The existing methods have neglected many issues like noise reduction and uneven illumination which will be presented in the output image of the existing haze removal algorithms. This dissertation has proposed a new haze removal technique HDCP which will integrate dark channel prior with CLAHE to remove the haze from color images and bilateral filter is used to reduce noise from images. Poor visibility not only degrades the perceptual image quality but it also affects the performance of computer vision algorithms such as surveillance system, object detection, tracking and segmentation. The proposed algorithm is designed and implemented in MATLAB. The comparison between dark channel prior and the proposed algorithm is also drawn based upon some standard parameters. The comparison has shown that the proposed algorithm has shown quite effective results.

Index terms*: Haze, HDCP, CLAHE and Bilateral filter.*

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I. INTRODUCTION

Poor visibility degrades image quality as well as the performance of the computer vision algorithms such as surveillance system, object detection, tracking and segmentation. Poor visibility is due to occurrence of atmospheric substances which absorbed light in between the object and camera. They can be the water droplets that are there in the air. These droplets are very small in size and they continuously float in the air and leads to the filths of the image when clicked in the bad weather conditions such as fog, haze and smog etc. Fog is a group of liquid water droplets or ice crystals hanging in the air at or near the Earth's surface. The term "fog" is typically distinguished from the more generic term "cloud" in that fog is low-lying [1]. In order to overcome the degradation in the image, visibility restoration methods are applied to the image so as to obtain a better quality of image. Visibility restoration can be considered as the different methods that aim to decrease or eradicate the degradation that have occurred while the digital image was being captured. The degradation may be due to various factors like relative camera-object motion, blur due to miss focus of camera, relative atmospheric turbulence and others. In this we will discuss about the degradations due to bad weather such as fog, haze, rain, snow and dust in an image. Light gets scattered in the atmosphere before it reaches the camera due to the presence of haze. The image quality of outdoor screen in the fog and haze weather condition is usually degraded by the scattering of a light before reaching the camera due to these large quantities of suspended particles (e.g. fog, haze, smoke, impurities) in the atmosphere. This scattering of light is caused due to the attenuation and airlight. The light coming from the object to be clicked gets scattered due to the presence of fog and some part of it also travels to the camera and causes shift in the of the image being clicked. So in order to remove this color shift in the image various haze removal methods are used in order to improve the quality of the image [2]. Haze removal is a tough task because fog depends on the unknown scene depth information. Hence removal of fog requires the estimation of airlight map or depth map. Fog effect is the function of distance between camera and object [3].

II. LITERATURE REVIEW

Mengyang et al (2009) [1] has studied that bad weather, such as fog and haze can considerably degrade the visual quality of a scene. To surmount it, some methods have been proposed. A novel defogging principle just based on a single image using dark channel prior as basics of principle. After experimental analysis about the dark channel prior haze removal, they found that although dark channel prior reacts well in most situations, it also results in larger diffusion values in some specific situations. Cosidering on these situations, they proposed an iterative principle to alter the color distortion effected by higher diffusion. This kind of global or local modification can be achieved by relatively ideal compromise between natural color and image definition. Desai et al (2009) [2] studied that de-weathering a fog degraded image is an ill posed problem and existing techniques are of high difficulty and low flexibility. Desai et al gave a novel fuzzy logic based method, to de-weather fog-degraded images. Specially, air-light judgment is carried out using fuzzy logic carried by color correction for improved visibility. Due to its low complexity compared to conservative physics based solutions, this method makes real-time implementation possible on a mobile platform which is critical from a road safety viewpoint. Zhiyuan et al (2009) [3] has discussed that the images weaken by fog suffer from poor contrast. In order to overcome fog effect, a Contrast Limited Adaptive Histogram Equalization (CLAHE)-based method is presented. This method creates a maximum value to clip the histogram and readjusts the clipped pixels equally to each gray-level. It can enhance the image contrast while limit the noise. Proposed method converts the original image from RGB to HIS and then the intensity component of the HIS image is redefined by CLAHE. Finally, the HSI image is converted back to RGB image. A color image degraded by fog is used to calculate the effectiveness of the proposed method and apply the edge detection to the image. Jing et al (2010) [4] explained that imaging in poor weather is often degraded by scattering due to hanging particles in the atmosphere such as haze, fog and mist. They proposed a novel fast defogging method from a single image of a scene based on a fast bilateral filtering method. The complexity of this method is only a linear function of the number of input image pixels and thus allows a very fast performance. Implementations on different types of outdoor foggy images demonstrate that method achieves good restoration for color fidelity and contrast resulting in a large improvement in image visibility. Chao et al (2010) [5] has proposed a content adaptive technique for single image dehazing. Since the degradation level damaged by haze is connected to the depth of the scene and pixels in each specific part of the image (such as buildings, trees or other objects) tend to have similar depth to the camera. It is assumed that the degradation level affected by haze of each region is the same such that the transmission in each region should be similar as well. Based on these situations, each input image is divided into different regions and transmission is estimated for each region followed by modification by soft matting and the hazy images can be successfully recovered. Guo Fan et al (2010) [6] developed a simple but effective method for visibility restoration from a single image. The main benefit of the proposed method is no user interaction is needed. This allows the algorithm to be used for practical applications, such as surveillance, intelligent vehicle, etc. Another advantage is its speed, since the cost of calculating transmission map is really cut down by using Retinex technique on luminance component. Jing et al (2010) [7] discussed that imaging in poor weather is often harshly degraded by scattering due to floating particles in the atmosphere such as fog, haze and mist. Poor perceptibility becomes main problem for most outdoor vision applications. Jing et al proposed a novel fast dehazing technique from a single image of a scene based on a fast bilateral filtering method. The difficulty of this method is only a linear function of the number of input image pixels and this thus allows a very fast implementation. Nishino et al (2010) [8] studied that atmospheric conditions induced by hanging particles, such as fog and haze, severely change the scene appearance. They introduce a novel Bayesian probabilistic method that jointly predicts the scene albedo and depth from a single foggy image by fully leveraging their latent statistical structures. The idea is to model the image with a factorial Markov random field in which the scene albedo and depth are two statistically independent latent layers and to jointly estimate them. Nishino et al showed that exploited natural image and depth statistics as priors on these hidden layers and estimate the scene albedo and depth with a canonical expectation maximization algorithm with alternating minimization. Yan Wang et al (2010) [9] has studied that atmospheric conditions created by floating particles, such as fog and haze, cruelly degrade image quality. Haze removal from a single image of a weather-corrupted scene remains a difficult task, because the haze is based on the unknown depth information. In this paper, Yan Wang and Bo Wu introduced an improved single image de hazing method which is based on the atmospheric scattering physics-based models. Yan Wang and Bo Wu applied the local dark channel prior on selected region to estimate the atmospheric light, and obtain more accurate result. Zhiyuan Xu et al (2010) [10] has analyzed that the images affected by fog suffer from poor contrast. A foggy image contrast enhancement method based on Bilinear Interpolation Dynamic Histogram Equalization is used to enhance the contrast. First, the original foggy image is divided into sub-images of same size. Then the histogram of each sub-image is divided into sub-histograms without command and then new active values are allocated for all such sub-histograms. Finally, HE and Bilinear Interpolation methods are applied to the image respectively. Results show that the proposed method gave better quality of image. Houssam Halmaoui et al (2011) [12] has observed that driver assistance systems based on camera are strongly affected by the presence of foggy weather. The restoration of these images would improve the results of such systems as pre-processing. A method is proposed to improve the image contrast of foggy road scenes joining a physical approach, based on Koschmieder model and a signals approach, based on local histogram equalization. Simulated annealing is used to analyze the parameters of the method. He et al (2011) [13] has proposed a simple but effective image prior dark channel prior to eliminate haze from a single input image. The dark channel prior is a kind of data of outdoor haze-free images. It is based on a key inspection that most local patches in outdoor haze-free images include some pixels whose power is very low in at least one color channel. Using this prior with the haze imaging representation, the thickness of the haze is approximated and get better high-quality haze-free image. Results on a variety of cloudy images reveal that the power of the proposed prior. Moreover, a high-quality intensity map can also be obtained as a offshoot of fog removal. Li Peng et al (2012) [15] have proposed a novel atmospheric model–based defogging method from single image, for the image degraded by spreading due to atmospheric particles. The main advantage of the proposed algorithm compared with previous techniques is that it can condense the Halo and blocking effects physically. Transmission is estimated using local extremes standard and bilateral filter that a high class depth map can be obtained. Experiments on a variety of outdoor haze images exhibit that this method can repair well colors and contrast of the experimental objects, progress the visibility of image and keep away from the Halo and jamming effects effectively. Tripathi et al. (2012) [15] have studied that fog formation is due to attenuation and airlight. Airlight enhancess the whiteness in the scene and Attenuation reduces the contrast. Proposed method uses bilateral filter for the judgment of airlight and improve scene contrast. Proposed method is independent on the density of fog and does not need user interference. This algorithm is applicable on both color as well as grey scale images. Histogram equalization is used as a preprocessing step. This results better estimation of airlight map. The final airlight map is refined using bilateral filter. Histogram stretching of output image is performed as post processing step. This results a final defogged image.

III. GAPS IN LITERATURE SURVEY

Fog removal algorithms become more beneficial for numerous vision applications. It has been observed that the most of the existing research have mistreated numerous subjects. Following are the various research gaps concluded using the literature survey:-

1. The presented methods have neglected the techniques to reduce the noise issue which is presented in the output images of the existing fog removal algorithms.
2. Not much effort has focused on the hybrid approach of the dark channel prior and contrast limited adaptive histogram equalization.
3. Uneven illumination problem is also neglected by the most of the researchers.

IV. PROPOSED HAZE REMOVAL APPORACH

We develop a method which combines the two existing methods of fog removal and bilateral filter is applied to it. It is found that the proposed method is more suitable for obtaining the better quality of the image than the most of the existing methods. The results produced by the existing dark channel prior method have less PSNR value and more MSE. Therefore the overall objective is to improve the results by combining CLAHE with Dark channel prior method. The proposed algorithm is designed and implemented in MATLAB using image processing toolbox. The detailed algorithm for the proposed approach is given below:

Step1: First of all , a hazy image is passed to the system.

Figure 1: Input hazy Image

Step 2: Then bilateral filter is applied that removes the random noise from the input images.

Step 3: Now apply the dark channel prior to the image.

(a) Firstly, the dark channel of the hazy image is calculated.

Figure 2: Original Dark Channel Measured

(b) Secondly, the transmission map is calculated using the equation

$$t = 1 - w * \frac{D}{A}$$

Where t is transmission map, w is the weighted map, D is dark channel original, A is the atmospheric light.

Figure 3: Transmission map

(a) Then the transmission map is refined to remove the halo artifacts from the edges.

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Figure 4: Refined Transmission map

(b) Haze free image is restored using below equation

$$opi(j,l,i) = \frac{I(j,l,i)-A}{\max(t(j,1),t0)} + A$$

Where opi is output image.

Step 3: Once the dark channel prior is applied to the image, then contrast limited adaptive histogram equalization is applied to each color channel of the color image independently and final image is restored.

Figure 5: Final image Restored by the proposed method

V. EXPERIMENTAL RESULTS

In this section we will compare the results of the images by the existing and the proposed approaches. The images of the existing and the proposed approaches are shown as under.

Figure 6 (a) Restored Image by Existing Method (b) Restored image by proposed Method

Figure 6 (a) is showing the restored image by the existing approach and Figure 6 (b) is showing the restored image by the proposed method. The Figure 6 (b) gives the better results as compared to the Figure 6 (a).

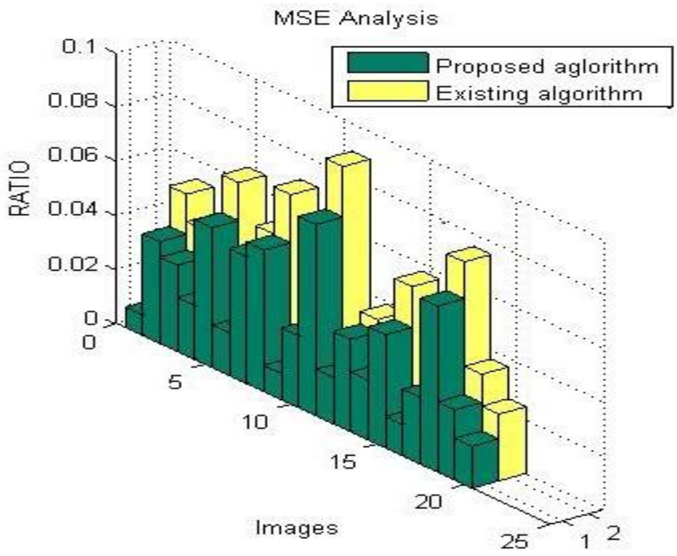
VI. PERFORMANCE ANALYSIS

The proposed algorithm is tested on different types of images. The algorithm is applied using some performance indices peak signal to noise ratio (PSNR), Mean squared error (MSE), Root Mean Square Error (RMSE), Average Difference (AD) and Bit Error Rate (BER). Implementation of the proposed algorithm has been done in MATLAB using image processing toolbox. The developed approach is compared against a well-known image dehazing technique available in literature that is Dark Channel Prior. We are comparing proposed approach using some performance metrics. Result shows that our proposed approach gives better results than the existing technique.

Table 1.1 is showing the quantized analysis of the mean square error. As MSE need to be reduced therefore the proposed algorithm is showing the better results than the available methods as mean square error is less in every case. The mean Square error is reduced in each case than the existing dark channel prior method. The proposed method is tested on the number of images and in each case shows the better results than the existing method.

Table 1.1 Mean Square Error Evaluation

Image name	Existing algorithm	Proposed algorithm
image 1	0.0104	0.0075
image 2	0.0523	0.0375
image3	0.0422	0.0318
image4	0.0252	0.0199
image5	0.0655	0.0515
image6	0.0213	0.0157
image7	0.0525	0.0468
image8	0.0699	0.0522
image9	0.0149	0.0097
image10	0.0333	0.0265
image11	0.0892	0.0706
image12	0.0199	0.0171
image13	0.0387	0.0341
image14	0.0302	0.0221
image15	0.0568	0.0417
image16	0.0157	0.0116
image17	0.0287	0.0246
image18	0.0748	0.0612
image19	0.0363	0.0259
Image20	0.0246	0.0154



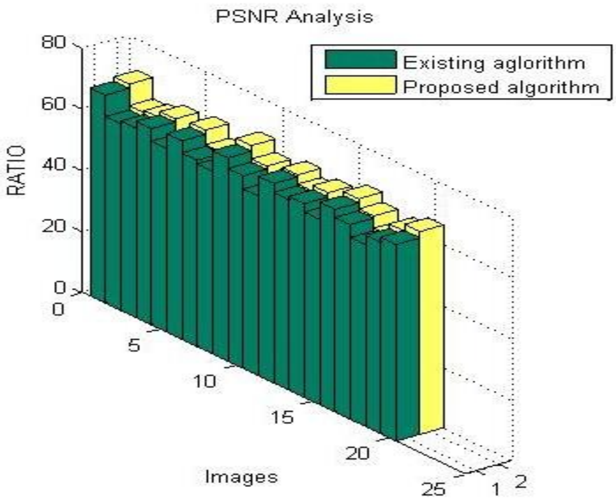
Graph 1.1 MSE of Existing Approach and Proposed Approach for different images

Graph 1.1 has shown the quantized analysis of the mean square error of different images using Dark Channel prior (yellow color) and by Proposed Approach (green color). It is very clear from the graph that there is decrease in MSE value of images with the use of proposed method over existing method. This decrease represents improvement in the objective quality of the image.

Table 1.2 is showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so the main goal is to increase the PSNR as much as possible. Table 1.2 has clearly shown that the PSNR is maximum in the case of the proposed algorithm; therefore proposed algorithm is providing better results than the existing methods. The proposed technique is tested on the number of images and in each case shows the better results than the existing method.

Table 1.2 Peak Signal to Noise Ratio Evaluation

Image name	Existing algorithm	Proposed algorithm
image 1	67.9435	69.3837
image 2	60.9458	62.3900
image3	61.8817	63.1007
image4	64.1103	65.1365
image5	59.9677	61.0099
image6	64.8479	66.1853
image7	60.9318	61.4319
image8	59.6886	60.9538
image9	66.4076	68.2803
image10	62.9109	63.9061
image11	58.6282	59.6438
image12	65.1440	65.8108
image13	62.2511	62.8072
image14	63.3277	64.6842
image15	60.5855	61.9325
image16	66.1643	67.4708
image17	63.5542	64.2277
image18	59.3939	60.2616
image19	62.5299	64.0012
Image20	64.2176	66.2469



Graph 1.2 PSNR of Existing Approach & Proposed Approach for different images

Graph 1.2 has shown the quantized analysis of the peak signal to noise ratio of different images using Dark Channel prior (green color) and by Proposed Approach (yellow color). It is very clear from the plot that there is increase in PSNR value of images with the use of proposed method over existing techniques. This increase represents improvement in the objective quality of the image.

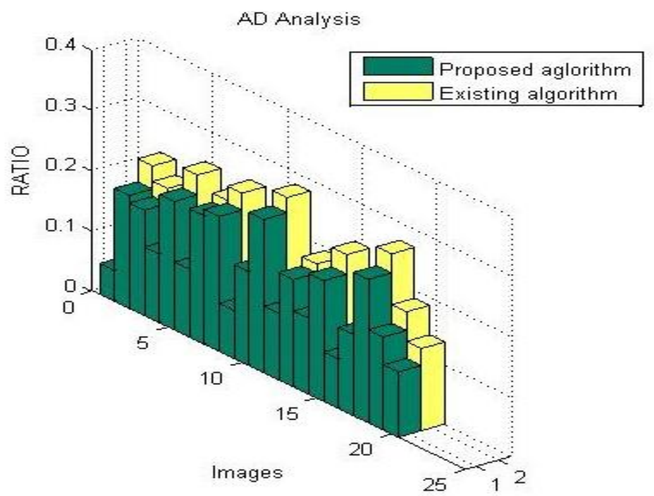
Table 1.3 is showing the comparative analysis of the Average Difference. As Average Difference needs to be minimized; so the main objective is to reduce the Average Difference as much as possible. Table 1.3 has clearly shown that Average Difference is less in our case therefore the proposed algorithm has shown significant results over the available algorithm.

Table 1.3 Average Difference Evaluation

Image name	Existing algorithm	Proposed algorithm
image 1	0.0773	0.0509
image 2	0.2256	0.1874
image3	0.1999	0.1748

image4	0.1156	0.1137
image5	0.2459	0.2129
image6	0.1308	0.1126
image7	0.2275	0.2129
image8	0.2514	0.2234
image9	0.1062	0.0796
image10	0.1782	0.1560
image11	0.2797	0.2544
image12	0.1236	0.1102
image13	0.1932	0.1782
image14	0.1483	0.1263
image15	0.2324	0.2001
image16	0.1119	0.0819
image17	0.1561	0.1347
image18	0.2694	0.2378
image19	0.1851	0.1543
Image20	0.1362	0.1081

Graph 1.3 has shown the quantized analysis of the Average Difference of different images using Dark Channel prior (yellow color) and by Proposed Approach (green color). Plot shows that there is decrease in AD value of images with the use of proposed method over existing method. This decrease represents improvement in the objective quality of the image.



Graph 1.3 Average Difference of Existing Approach & Proposed Approach for different images

VII. CONCLUSION AND FUTURE SCOPE

Haze removal algorithms become more beneficial for many vision applications. It is found that most of the existing researchers have neglected many issues; i.e. no technique is better for different kind of situations. The existing methods have neglected the use of CLAHE and bilateral filter to reduce the noise and uneven illumination problem which will be presented in the output image of the existing haze removal algorithms. To reduce the problems of existing literature, a new hybrid algorithm has been proposed that has integrated the dark channel prior with CLAHE to enhance the results further. The proposed algorithm is designed and implemented in MATLAB using image processing toolbox. Various kinds of images are taken for experimental purpose. The comparison among dark channel prior and the proposed algorithm is also drawn based upon some standard parameters. The comparison analysis has shown that the proposed algorithm has shown quite effective results.

In future we will modify the proposed algorithm further by integrating with some well-known filters like guided filter, switching median filter etc. However the role of color correction algorithms has also been neglected in this research work, so future we will also use some color correction algorithms.

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